

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

The nutrition and growth of lambs reared artificially
with or without meal

A thesis presented in partial fulfilment of the requirements for the
degree of

Master of Science

in

Animal Science

at Massey University, Manawatu, New Zealand.

Amber Celeste Myles Jensen

2017

Abstract

Jensen, A. (2017). The nutrition and growth of lambs reared artificially with or without meal.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Animal Science at Massey University, Manawatu, New Zealand.

Artificial rearing is routinely used in large-scale dairy sheep farms. One approach is to offer milk replacer (MR) and meal *ad libitum* to lambs. The aim was to evaluate the growth of female lambs in the first 12 weeks of rearing with (M) and without (NM) grain-based meal access (n=30/group) during four feeding periods. In period 1 (week 0-3), lambs were offered MR and meal *ad libitum*, and in period 2 (week 4-5) were transitioned outdoors onto pasture with continued access to MR and meal. Lambs were weaned off MR in period 3 (week 6-10), and meal in period 4 (week 10-12). The NM lambs received identical management, but meal was excluded. A treatment-by-time interaction was found whereby NM lambs had lower average daily gain (ADG) ($P<0.05$) in periods 1 (376 ± 6 vs. 414 ± 8 g/d) and 3 (146 ± 7 vs. 241 ± 7 g/d), no difference in period 2 ($P>0.05$), and higher ADG in period 4 (157 ± 18 vs. -55 ± 18 g/d, $P<0.05$) than M lambs. These results indicate that when lambs fed MR *ad libitum* are offered unrestricted access to good-quality pasture before weaning, meal may not be required to achieve a similar live weight at 12 weeks of age.

Data from the aforementioned experiment were further investigated by week to allow investigations of the relationship between nutrient intake and growth, describe variation in ADG in relation to environmental and feeding transitions, and to estimate pasture intakes, which were not measured. The different feeding transitions, nutrient intakes, and feeds were most likely causing the differences in ADG that occurred between treatment groups and weeks. The greatest variation in ADG of lambs occurred in the M lambs after meal

weaning, which was likely due to a poor adaption to a pasture-only diet. Pasture intakes were estimated by calculating lamb requirements for maintenance and growth from actual ADG and live-weight measurements, assuming that pasture intake made up the difference between actual intakes and theoretical intakes. It was found there were significant differences in estimated pasture intakes between M and NM lambs ($P < 0.0001$) and intakes changed over weeks. In weeks seven, eight, and nine, M lambs were estimated to not consume any pasture, due to a high intake of meal, to achieve the observed growth rates. However, NM lambs consumed pasture over these weeks as pasture was their only feed source. These results allow speculation that pasture intake was very low in M lambs before meal was removed. It has been previously reported that high meal intakes when combined with low roughage intake can negatively impact rumen health and development, and transitioning from high meal to high roughage diets requires alterations in the ruminal microbe population and fermentation. The estimated low pasture intake before meal weaning, combined with the high meal intake recorded, may have contributed to the growth check that occurred once meal was removed, as lambs required a period to adapt to the pasture diet, as their rumen underwent the changes associated with transitioning between these diets. Further investigation into differences in pasture intake between lambs reared with and without meal, and more evidence as to what caused the growth check after meal weaning may allow further optimisation of different lamb-rearing systems.

Acknowledgements

I would like to sincerely thank my supervisors Sam Peterson and Patrick Morel (Massey University), and Sue McCoard (AgResearch) for their tireless help and guidance. I would like to thank the AgResearch-led Ministry of Business, Innovation, and Employment “Boosting exports of the emerging NZ dairy sheep industry” program for funding this research, in partnership with Kingsmeade Artisan Cheese, Maui Milk, and Spring Sheep Milk Co. I would also like to thank the Animal Nutrition & Physiology Team and Ulyatt-Reid Large Animal Facility staff from AgResearch Limited Grasslands for their assistance with animal care and data collection.

A great many thanks to Ajmal Khan, Frederik Knol, Catherine McKenzie, and David Stevens for their feedback and assistance in the writing of this thesis and analysis of results. I would also like to acknowledge the Lois Turnbull Postgraduate scholarship for personal funding.

Table of contents

Abstract.....	i
Acknowledgements.....	iii
Table of contents	iv
List of tables	vi
List of figures.....	vii
List of abbreviations.....	ix
Chapter 1: A review of some of the factors affecting lamb growth in artificial-rearing systems.....	2
1.1 Introduction	2
1.2 Artificial rearing.....	3
1.3 Milk source and composition.....	5
1.4 Nutrient requirements.....	8
1.5 Solid feeding, digestion, and growth	9
1.5.1 Onset of solid intake	10
1.5.2 Different types of solid feed and composition	11
1.5.3 Digestive tract development.....	13
1.5.4 Pre-ruminant and ruminant digestion	14
1.5.4.1 Carbohydrates.....	15
1.5.5 Rumen development.....	21
1.5.6 Transitions between solid feeds	25
1.6 Volume of milk replacer fed.....	26
1.7 Compensatory growth	30
1.8 Growth check	32
1.8.1 Volume of milk intake	32
1.8.2 Type of weaning.....	33
1.8.3 Post-weaning diet	36
1.8.4 Weaning weight	36
1.8.5 Age at weaning.....	37
1.8.6 Habitat.....	37
1.9 The effects of litter size and birth weight on growth	38
1.10 Sex effects on growth	43
1.11 Breed.....	44
1.12 Post-weaning growth.....	45

1.13	Conclusion.....	48
1.13.1	Objectives.....	48
Chapter 2: How does feeding meal affect growth of artificially reared East Friesian-cross dairy lambs?		
	50
2.1	Introduction	50
2.2	Materials and methods	51
2.2.1	Experimental design.....	51
2.2.2	Animal and feed measurements.....	53
2.2.3	Statistical analysis	55
2.3	Results.....	56
2.3.1	Lamb average daily gain and live weight	56
2.3.2	Intake	58
2.4	Discussion.....	59
Chapter 3: Further investigation into nutrient intake and lamb growth, and estimation of pasture intake		62
3.1	Introduction	62
3.2	Methods.....	64
3.2.1	Calculations.....	64
3.2.2	Statistical analysis	65
3.3	Results.....	66
3.3.1	Average daily gain	66
3.3.2	Milk replacer and meal intake	70
3.3.3	Nutrient intakes	71
3.4	Discussion.....	77
3.4.1	Average daily gain and nutrient intake.....	77
3.4.2	Individual variation in average daily gain.....	86
3.5	Conclusions	88
Chapter 4: General discussion		89
5	References	95

List of tables

Table 1.1 Some published representative examples of the composition of ewes' milk and cows' milk	8
Table 1.2 Average daily gain (ADG) of lambs fed restricted milk replacer (MR) or <i>ad libitum</i>	30
Table 1.3 Post-weaning average daily gain (ADG) of lambs that were fed different levels of milk replacer (MR) before weaning	47
Table 2.1 Composition of pasture grazed by lambs in two treatment groups (meal feeding (M) and no meal feeding (NM)) over three periods of milk and meal (M lambs) or milk feeding (NM lambs) (period 2), pasture (NM) or pasture and meal feeding (M) (period 3), and pasture feeding only in both groups (period 4)	54
Table 2.2 Average daily milk replacer (MR) and meal intake per lamb (mean±SEM) and intake (mean±SEM) of dry matter, metabolisable energy, and crude protein from MR and meal sources for M (fed meal) and NM (not fed meal). In period 1 (P1; week 0-3), MR was provided to both treatment groups and meal offered to M lambs. In period 2 (P2; week 4-5), all lambs were offered unrestricted pasture and MR <i>ad libitum</i> , and meal offered to M lambs <i>ad libitum</i> . In period 3 (P3; week 6-10), no MR was offered, and M lambs had access to meal <i>ad libitum</i>	58
Table 3.1 Average weekly theoretical metabolisable energy intake (MEI) and theoretical crude protein intake (CPI) for M (fed meal) and NM (not fed meal) lambs to achieve the observed growth rates. Feeding regime of milk replacer (MR), meal, and pasture is shown in the table for M lambs, and NM lambs received the same treatment except meal was excluded. All diets were provided <i>ad libitum</i>	72
Table 3.2 Actual metabolisable energy (ME) and crude protein (CP) concentrations of pasture used to estimate the amount of pasture that was required to meet ME and CP requirements for maintenance and growth of lambs.....	75
Table 3.3 The contribution (%) of each feed source to total metabolisable energy (ME) intake for M (fed meal) and NM (not fed meal) lambs. Milk replacer (MR) and meal intakes are actual intakes, while pasture is calculated as the amount that was required to be consumed to meet lambs' calculated growth and maintenance requirements.....	76
Table 3.4 The contribution (%) of each feed source to total crude protein (CP) intake for M (fed meal) and NM (not fed meal) lambs. Milk replacer (MR) and meal intakes are actual intakes, while pasture is calculated as the amount that was required to be consumed to meet lambs' calculated growth and maintenance requirements.....	76

List of figures

Figure 1.1. The ruminant digestive system showing the four different compartments (rumen, reticulum, omasum, and abomasum) in new-born ruminants (A) and mature ruminants (B). The oesophageal groove is shown in the new-born system (A). Figures are not drawn to the same scale. Source: FAO, 2011.....14

Figure 1.2. Change in number, width, and length of papillae in the rumen of lambs fed a milk-only diet to 84 days of age. Source: Lane et al., 2000.....24

Figure 1.3. Weight of lambs from day 0 to day 28 after weaning for different weaning regimes. All lambs were weaned around 12 kg, therefore, there may be confounding effects of age. Abrupt: lambs were abruptly weaned from *ad libitum* milk replacer. Limited access: access to milk replacer that had previously been provided *ad libitum* was restricted by reducing the number of times lambs could feed over five days. Diluted: milk replacer continued to be provided *ad libitum*, but milk powder was mixed at 100 g/L compared to previous concentration of 200 g/L. There was a significant difference between the abruptly weaned lambs and the other two groups Source: Bimczok et al., 2005.....35

Figure 2.1 Average daily gain (mean±SEM) of lambs fed meal (M; ■) or no meal (NM; □) over four feeding periods. In period 1 (week 0-3), milk replacer (MR) was provided to both treatment groups and meal offered to M lambs. In period 2 (week 4-5), all lambs were offered unrestricted pasture and MR *ad libitum*, and meal offered *ad libitum* to M lambs. In period 3 (week 6-10), no MR was offered, and M lambs had access to meal *ad libitum*. In period 4 (week 10-12), all lambs had unrestricted access to pasture. There was a significant treatment-by-time interaction ($P<0.001$). ^{ab} Values with different superscripts within each period are significantly different ($P<0.05$).....56

Figure 2.2 Average live weight (mean±SEM) of lambs fed meal (M; ■) or no meal (NM; □) at weeks 3, 5, 10, 12. In period 1 (week 0-3), milk replacer (MR) was provided to both treatment groups and meal offered to M lambs. In period 2 (week 4-5), all lambs were offered unrestricted pasture and MR *ad libitum*, and meal offered to M lambs *ad libitum*. In period 3 (week 6-10), no MR was offered, and M lambs had access to meal *ad libitum*. In period 4 (week 10-12), all lambs had unrestricted access to pasture. There was a significant treatment-by-time interaction ($P<0.001$). ^{ab} Values with different superscripts within each period are significantly different ($P<0.001$).....57

Figure 3.1 Weekly average daily gain (mean±SEM) of lambs fed meal (M; ■) or no meal (NM; □). In weeks one to three, lambs were indoors and milk replacer (MR) was provided to all and M lambs were fed meal in addition to MR. In weeks four and five, lambs were outdoors grazing unrestricted pasture and continued to receive MR *ad libitum* and M lambs were still offered meal *ad libitum*. From week six to ten, no MR was fed, but M lambs had continued access to meal *ad libitum*, until it was gradually weaned over ten days in weeks nine and ten. From halfway through week ten to week 12, lambs' only source of feed was

pasture. There was a significant treatment-by-time interaction ($P<0.001$). ^{ab} Values with different superscripts are significantly different both within and between treatment groups over time ($P<0.001$).....67

Figure 3.2 Box and whisker diagram showing variation in average daily gain (ADG) of lambs fed meal (M; ■) or no meal (NM; ■). In weeks one to three, lambs were indoors and milk replacer (MR) was provided and M lambs were fed meal in addition to MR. In weeks four and five, lambs were outdoors grazing unrestricted pasture and continued to receive MR *ad libitum* and M lambs were still offered meal *ad libitum*. From week six to ten, no MR was fed, but M lambs had continued access to meal *ad libitum*, until it was gradually weaned over ten days in weeks nine and ten. From halfway through week ten to week 12, lambs' only source of feed was pasture. Whiskers represent the top and bottom 25% of observations and the box represents the interquartile range (IQR) and middle 50% of observations, with the line within the box representing the median. * represents outliers (more than 1.5 times the IQR from the upper and lower quartile.....69

Figure 3.3 Average daily milk replacer (MR) intake (mean±SEM) for M (dotted line) and NM lambs (solid line) and meal intake (mean±SEM) for M lambs (dashed line) on secondary axis. In weeks one to three lambs were housed indoors and fed MR *ad libitum*. In weeks four and five, lambs were kept on unrestricted pasture and continued to have access to MR *ad libitum*. Lambs were abruptly weaned from MR at the end of week five. Until week eight, meal was fed to M lambs *ad libitum*, and was then gradually weaned over ten days in weeks nine and ten. * indicates a significant difference ($P<0.001$) between treatment groups.....70

Figure 3.4 (a) Metabolisable energy (ME; solid line) and crude protein (CP; dotted line) intake (mean±SEM) from milk replacer (MR) and meal sources for M (blue) and NM lambs (orange). (b) Weekly estimated pasture intake (mean±SEM) that was required to meet ME¹ (Solid line) and CP² (dotted line) calculated maintenance requirements and requirements for the growth recorded for M (blue) and NM (orange) lambs. (c) Average daily gain (mean±SEM) of M (blue) and NM (orange) lambs. In weeks one to three lambs were indoors and fed MR and meal *ad libitum*, they were moved outdoors in week four, and MR and meal continued to be fed. Lambs were abruptly weaned from MR at the end of week five. Meal continued to be fed until week eight, when it was gradually weaned over ten days, so that all meal was removed part-way through week ten. NM lambs received same treatment except meal was excluded. ¹Estimated pasture DMI for ME=Theoretical MEI – actual MEI x pasture ME composition. ²Estimated pasture DMI for ME=Theoretical CPI – actual CPI x pasture CP composition. * indicates a significant difference between treatment groups ($P<0.05$).....74

List of abbreviations

a	Metabolisable energy requirement for maintenance
ADF	Acid detergent fibre
ADG	Average daily gain
ANOVA	Analysis of variance
ATP	Adenosine triphosphate
b	Metabolisable energy required for growth
c	Crude protein
CMR	Milk replacer designed to be fed to calves
CP	Crude protein requirement for maintenance
CPI	Crude protein intake
CPgrowth	Crude protein that was required for growth (calculated for this trial)
CPmaintenance	Crude protein required for maintenance (calculated for this trial)
CPtheoretical	Calculated crude protein required to meet calculated maintenance and growth requirements
d	Crude protein required for growth
DM	Dry matter
DMI	Dry matter intake
g/d	grams per day
GE	Gross energy
K _g	Efficiency of utilisation of metabolisable energy for growth
Kg	kilograms
LMR	Milk replacer designed to be fed to lambs
LWT	Live weight
LWTend	Live weight at the end of the week
LWTstart	Live weight at the start of the week
ME	Metabolisable energy
MEI	Metabolisable energy intake

ME _{growth}	Metabolisable energy that was required for growth (calculated for this trial)
ME _{maintenance}	Metabolisable energy required for maintenance (calculated for this trial)
ME _{theoretical}	Calculated metabolisable energy required to meet calculated maintenance and growth requirements
MJ	Megajoules
MR	Milk replacer
M	Lambs allowed meal
NDF	Neutral detergent fibre
NM	Lambs not fed any meal
OMD	Organic matter digestibility
P	Period
REML	Repeated-measure mixed-effects model
TCA cycle	Tricarboxylic acid cycle
VFAs	Volatile fatty acids

